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(54) **ENCODING AND DECODING MOTION VIA IMAGE SEGMENTATION**

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(52) **U.S. Cl.**

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CPC ... H04N 19/105; H04N 19/137; H04N 19/17; H04N 19/186

See application file for complete search history.

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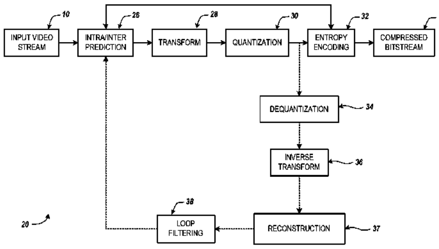
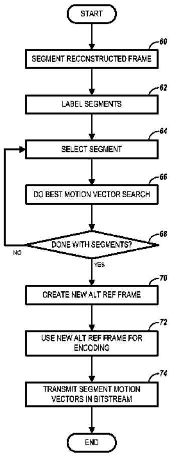
(57) **ABSTRACT**

A system and method for encoding and decoding a video image having a plurality of frames is disclosed. The method includes a previously reconstructed frame that is segmented to create an alternate reference frame used to encode a current frame. The segments of the previously reconstructed frame are assigned motion parameters, which are used to compile the alternate reference frame. The current frame is encoded and the segmentation parameters and motion parameters are transmitted in the bitstream. The segmentation parameters and motion parameters can be used by a decoder to recreate the alternate reference frame in order to decode the encoded current frame.

16 Claims, 8 Drawing Sheets




START
60
SEGMENT RECONSTRUCTED FRAME
62
LABEL SEGMENTS
64
SELECT SEGMENT
66
DO BEST MOTION VECTOR SEARCH
68
DONE WITH SEGMENTS?
NO
YES
70
CREATE NEW ALT REF FRAME
72
USE NEW ALT REF FRAME FOR ENCODING
74
TRANSMIT SEGMENT MOTION VECTORS IN BITSTREAM
END

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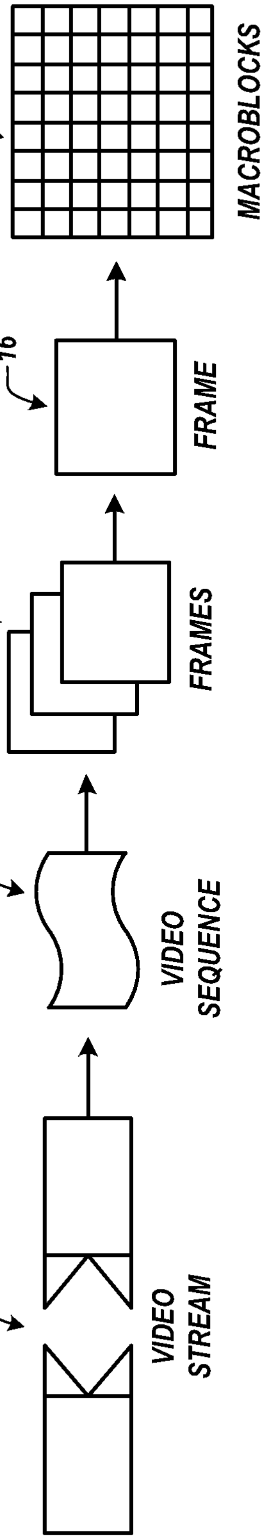
10
VIDEO STREAM
12
VIDEO SEQUENCE
14
FRAMES
16
FRAME
18
MACROBLOCKS

FIG. 1

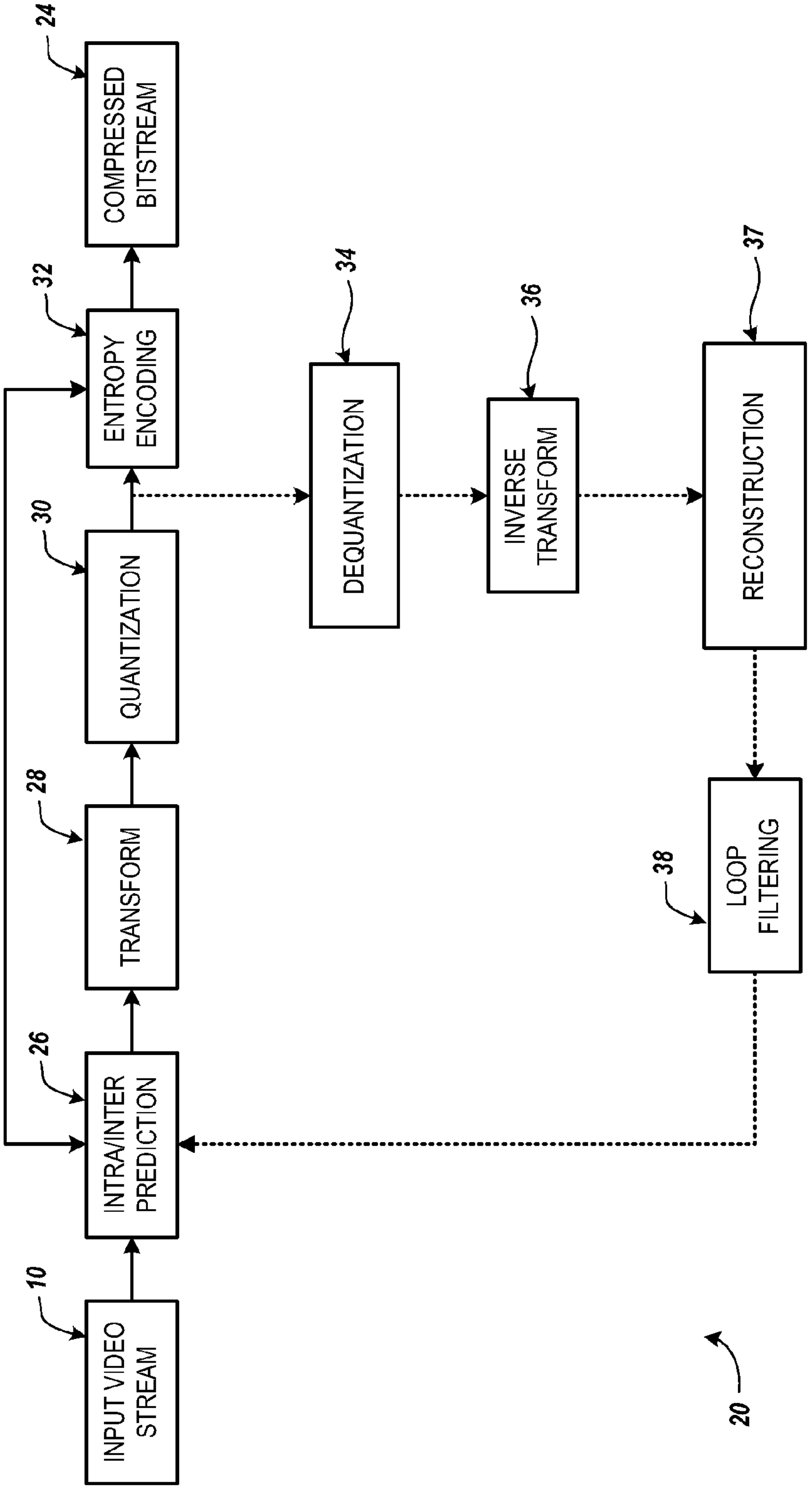
INPUT VIDEO STREAM
10
INTRA/INTER PREDICTION
26
TRANSFORM
28
QUANTIZATION
30
ENTROPY ENCODING
32
COMPRESSED BITSTREAM
24
DEQUANTIZATION
34
INVERSE TRANSFORM
36
RECONSTRUCTION
37
LOOP FILTERING
38
20

FIG. 2

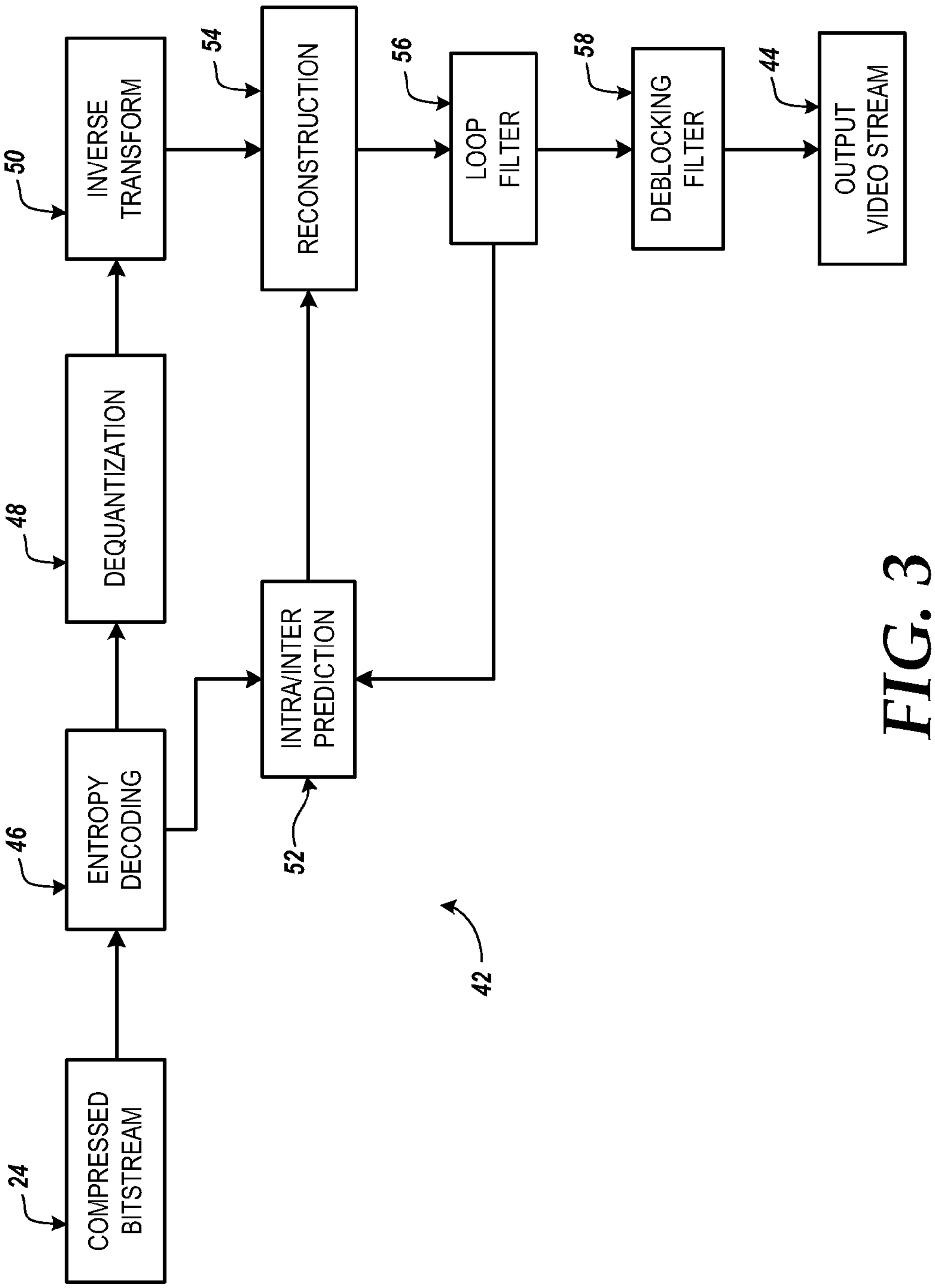
24
COMPRESSED BITSTREAM
46
ENTROPY DECODING
48
DEQUANTIZATION
50
INVERSE TRANSFORM
52
INTRA/INTER PREDICTION
54
RECONSTRUCTION
56
LOOP FILTER
58
DEBLOCKING FILTER
44
OUTPUT VIDEO STREAM
42

FIG. 3

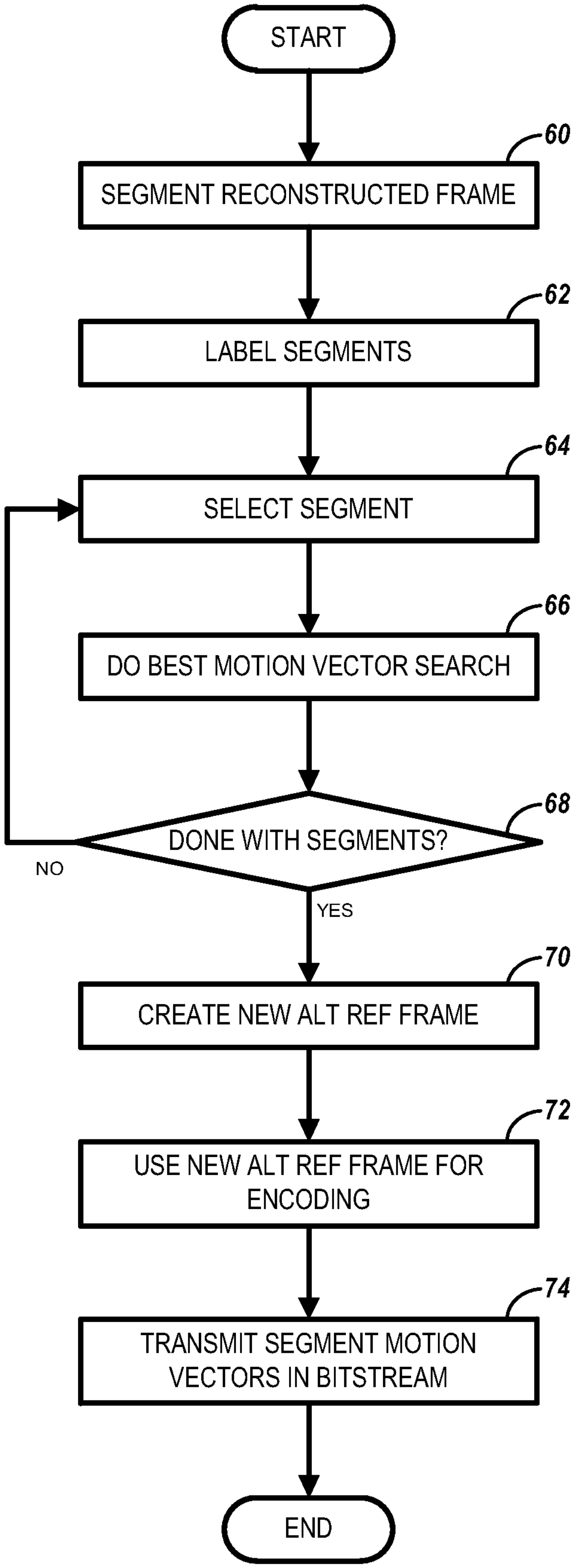
START
60
SEGMENT RECONSTRUCTED FRAME
62
LABEL SEGMENTS
64
SELECT SEGMENT
66
DO BEST MOTION VECTOR SEARCH
68
DONE WITH SEGMENTS?
NO
YES
70
CREATE NEW ALT REF FRAME
72
USE NEW ALT REF FRAME FOR ENCODING
74
TRANSMIT SEGMENT MOTION VECTORS IN BITSTREAM
END

FIG. 4

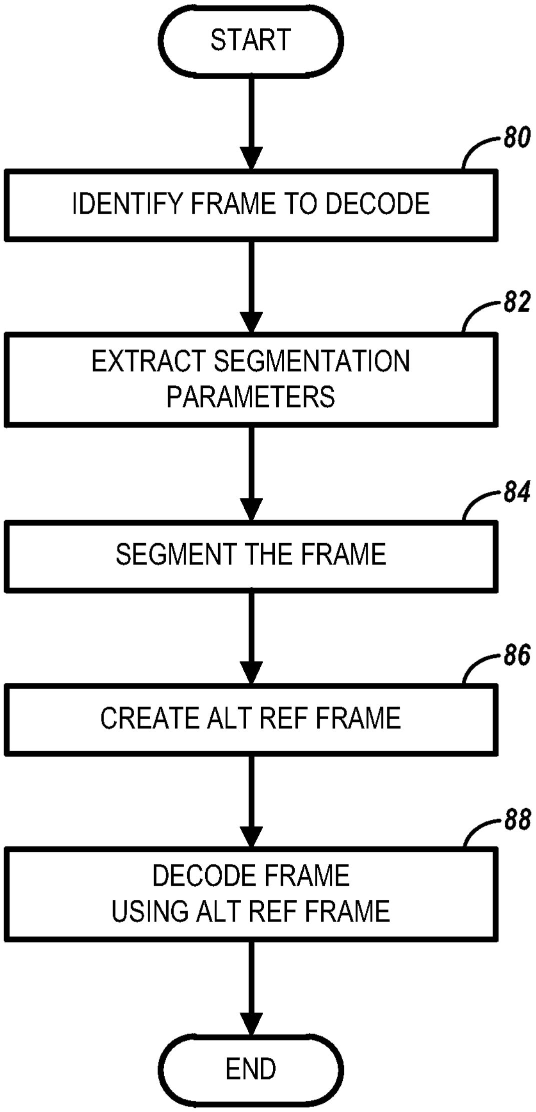
START
80
IDENTIFY FRAME TO DECODE
82
EXTRACT SEGMENTATION PARAMETERS
84
SEGMENT THE FRAME
86
CREATE ALT REF FRAME
88
DECODE FRAME USING ALT REF FRAME
END

FIG. 5

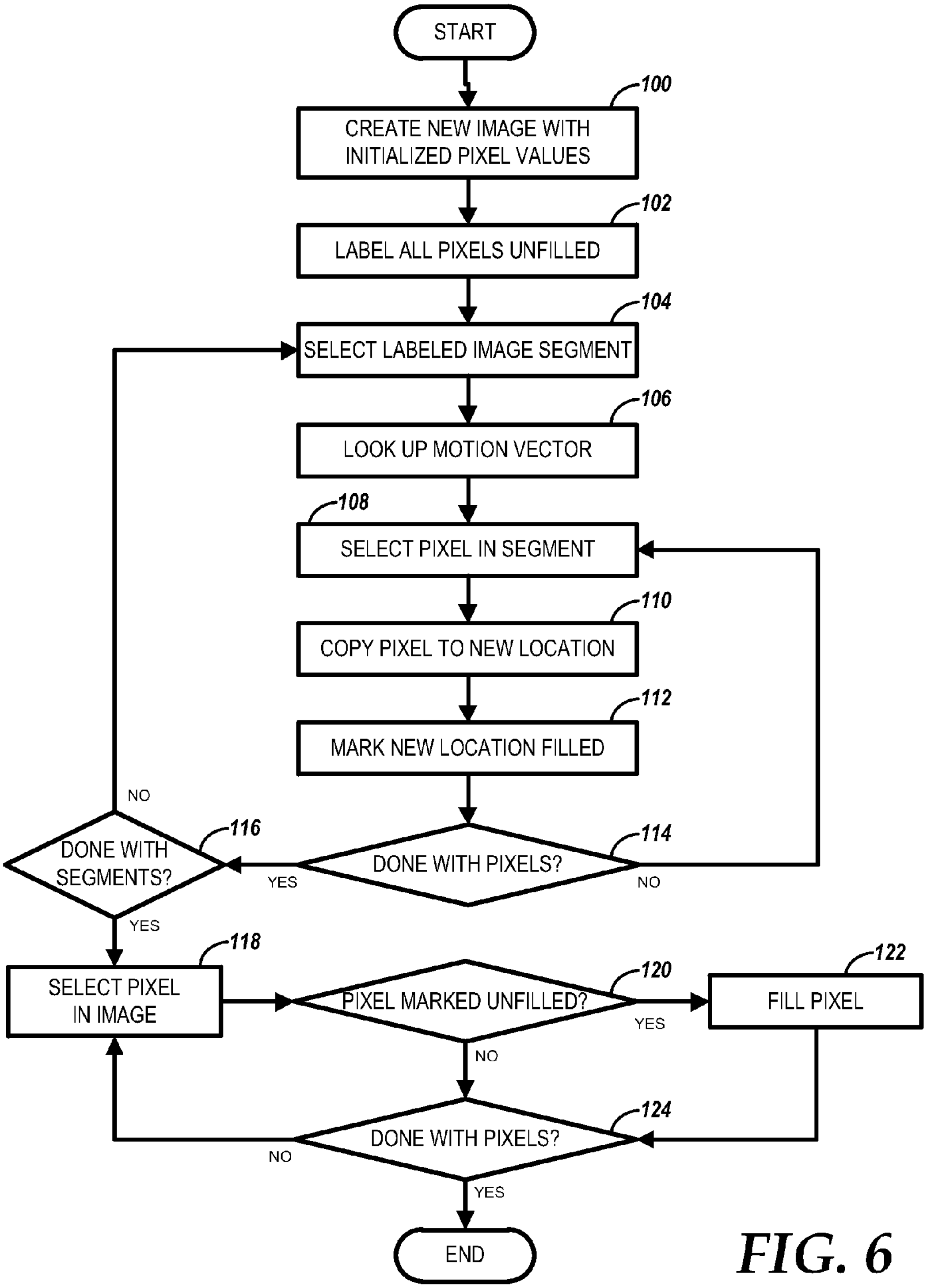
START
100
CREATE NEW IMAGE WITH INITIALIZED PIXEL VALUES
102
LABEL ALL PIXELS UNFILLED
104
SELECT LABELED IMAGE SEGMENT
106
LOOK UP MOTION VECTOR
108
SELECT PIXEL IN SEGMENT
110
COPY PIXEL TO NEW LOCATION
112
MARK NEW LOCATION FILLED
NO
116
DONE WITH SEGMENTS?
114
DONE WITH PIXELS?
YES
NO
YES
118
SELECT PIXEL IN IMAGE
120
PIXEL MARKED UNFILLED?
YES
122
FILL PIXEL
NO
124
DONE WITH PIXELS?
NO
YES
END

FIG. 6

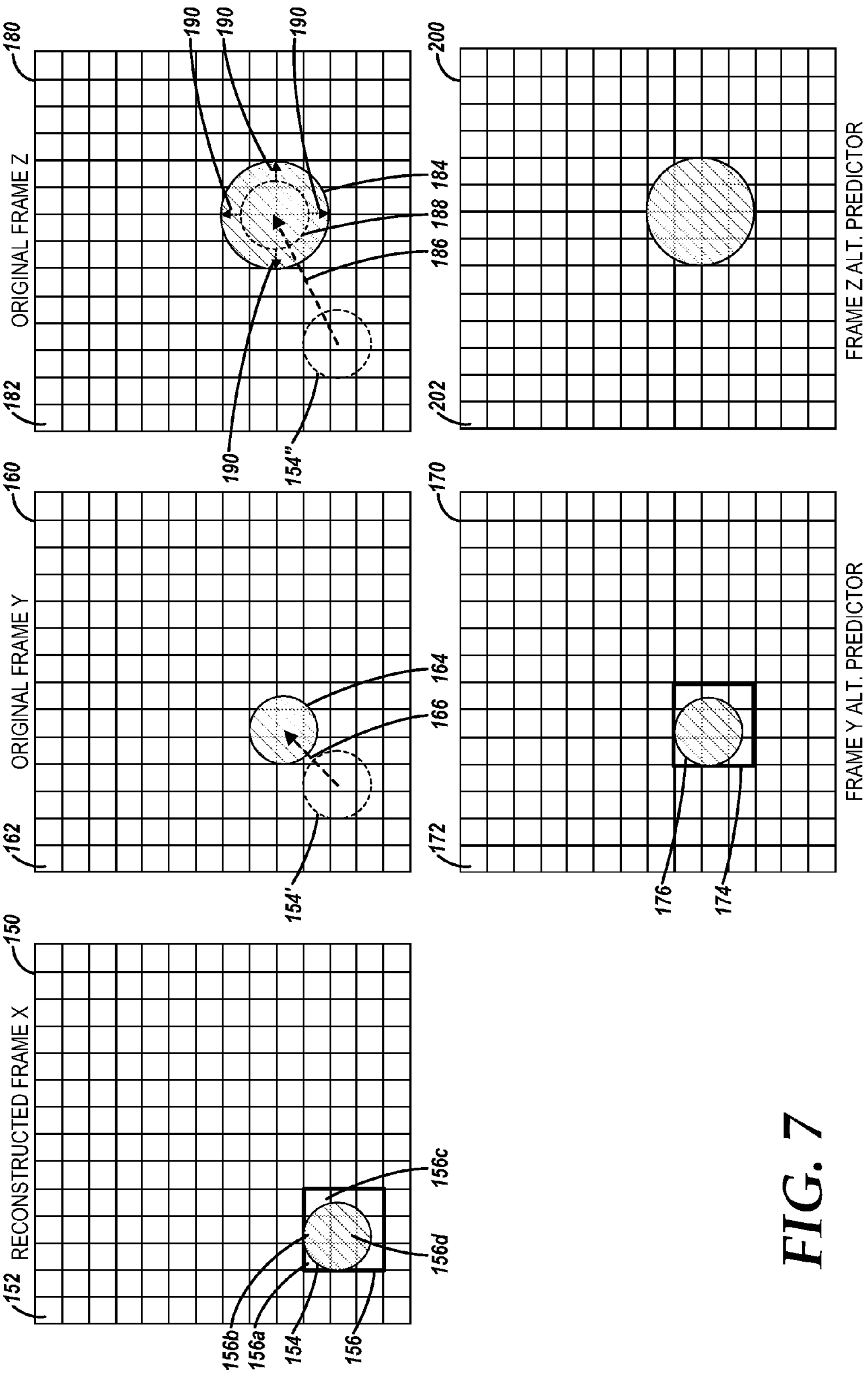
RECONSTRUCTED FRAME X
150
152
154
156
156a
156b
156c
156d
ORIGINAL FRAME Y
160
162
164
166
154'
FRAME Y ALT. PREDICTOR
170
172
174
176
ORIGINAL FRAME Z
180
182
184
186
188
190
190
190
190
154"
FRAME Z ALT. PREDICTOR
200
202

FIG. 7

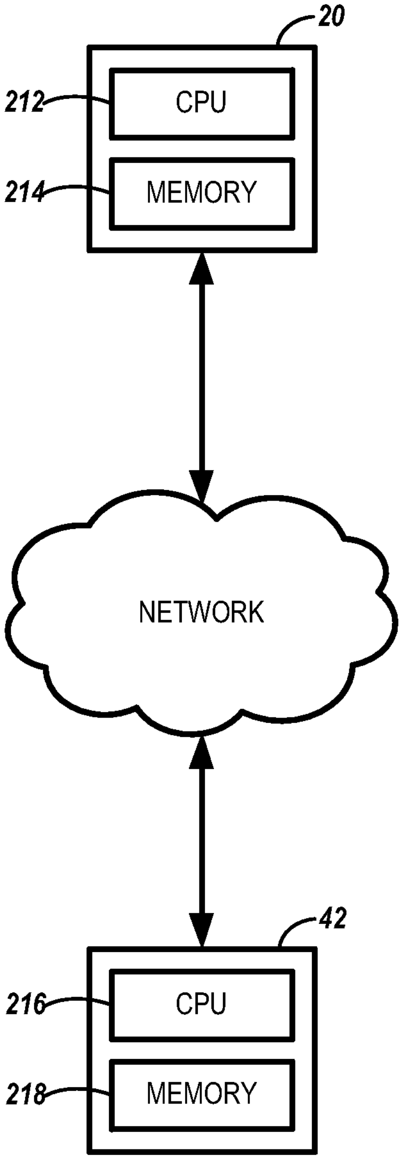

FIG. 8

ENCODING AND DECODING MOTION VIA IMAGE SEGMENTATION

TECHNICAL FIELD

The present invention relates in general to video encoding and decoding.

BACKGROUND

An increasing number of applications today make use of digital video for various purposes including, for example, remote business meetings via video conferencing, high definition video entertainment, video advertisements, and sharing of user-generated videos. As technology is evolving, users have higher expectations for video quality and expect high resolution video even when transmitted over communications channels having limited bandwidth.

To permit higher quality transmission of video while limiting bandwidth consumption, a number of video compression schemes are noted including formats such as VPx, promulgated by Google Inc. of Mountain View, Calif., and H.264, a standard promulgated by ITU-T Video Coding Experts Group (VCEG) and the ISO/IEC Moving Picture Experts Group (MPEG), including present and future versions thereof. H. 264 is also known as MPEG-4 Part 10 or MPEG-4 AVC (formally, ISO/IEC 14496-10).

These compression schemes may use prediction techniques to minimize the amount of data required to transmit video information by using, for example, the spatial and temporal coherences in video information. Prediction techniques can allow for multiple past transmitted frames and future frames to be used as potential reference frame predictors for macroblocks in a frame.

SUMMARY

Systems, apparatuses and methods for encoding and decoding a video signal are disclosed. In accordance with one aspect of the disclosed embodiments, a method for encoding a current frame of a video signal having a plurality of frames, each frame having a plurality of pixels, is disclosed. One such method comprises segmenting a previously reconstructed frame into at least one image segment using a segmentation parameter, each image segment having a segment identifier, determining a motion parameter for each image segment using a processor, creating an alternate reference frame from the previously reconstructed frame using the motion parameter for at least certain of the image segments, and encoding the current frame using the alternate reference frame for inclusion in a bitstream.

An apparatus for encoding a current frame of a video signal having a plurality of frames, each frame having a plurality of pixels, includes in one exemplary embodiment means for segmenting a previously reconstructed frame into at least one image segment using a segmentation parameter, each image segment having a segment identifier, means for determining a motion parameter for each image segment, means for creating an alternate reference frame from the previously reconstructed frame using the motion parameter for each image segment, and means for encoding the current frame using the alternate reference frame for inclusion in a bitstream.

One method for decoding a video signal having a plurality of frames taught herein, where each frame has a plurality of pixels, comprises identifying a current frame to be decoded from a bitstream using a processor, the current frame having an associated previously reconstructed frame, a segmentation parameter, a plurality of segment identifiers and a motion parameter associated with each segment identifier, segmenting the previously reconstructed frame into a plurality of image segments using the segmentation parameter, each image segment associated with one of the segment identifiers, creating an alternate reference frame from the previously reconstructed frame using the motion parameter of at least certain of the image segments, and decoding the current frame using the alternate reference frame.

Variations of these methods and apparatuses and details of other aspects and embodiments are described in additional detail hereinafter.

BRIEF DESCRIPTION OF THE DRAWINGS

The description herein makes reference to the accompanying drawings wherein like reference numerals refer to like parts throughout the several views, and wherein:

FIG. **1** is a diagram of a video bitstream;

FIG. **2** is a block diagram of a video compression system in accordance with one embodiment;

FIG. **3** is a block diagram of a video decompression system in accordance with another embodiment;

FIG. **4** is a flow chart of a method of encoding with a new alternate reference frame synthesized using segmentation and motion compensation as implemented in the encoder of FIG. **2**;

FIG. **5** is a flow chart of a method of decoding with a new alternate reference frame synthesized using segmentation and motion compensation as implemented in the decoder of FIG. **3**;

FIG. **6** is a flow chart of a method of creating a new alternate reference frame using segments and motion vectors as shown in FIGS. **4** and **5**;

FIG. **7** is a schematic diagram illustrating exemplary frames of a video bitstream as used and created by the methods of FIGS. **4**-**6**; and

FIG. **8** is a block diagram of computer systems implementing the video compression system and video decompression system described herein.

DETAILED DESCRIPTION

FIG. **1** is a diagram a typical video bitstream **10** to be encoded and decoded. Video coding formats, such as VP8 or H.264, provide a defined hierarchy of layers for video stream **10**. Video stream **10** includes a video sequence **12**. At the next level, video sequence **12** consists of a number of adjacent frames **14**, which can then be further subdivided into a single frame **16**. At the next level, frame **16** can be divided into a series of blocks or macroblocks **18**, which can contain data corresponding to, for example, a 16×16 block of displayed pixels in frame **16**. Each macroblock can contain luminance and chrominance data for the corresponding pixels. Macroblocks **18** can also be of any other suitable size such as 16×8 pixel groups or 8×16 pixel groups. Herein, unless otherwise stated, the terms macroblocks and blocks are used interchangeably.

FIG. **2** is a block diagram of a video compression system in accordance with one embodiment. An encoder **20** encodes an input video stream **10**. Encoder **20** has the following stages to perform the various functions in a forward path (shown by the solid connection lines) to produce an encoded or a compressed bitstream **24**: an intra/inter prediction stage **26**, a transform stage **28**, a quantization stage **30** and an entropy encoding stage **32**. Encoder **20** also includes a reconstruction path (shown by the dotted connection lines) to reconstruct a frame for encoding of further macroblocks. Encoder **20** has the following stages to perform the various functions in the reconstruction path: a dequantization stage **34**, an inverse transform stage **36**, a reconstruction stage **37** and a loop filtering stage **38**. Other structural variations of encoder **20** can be used to encode input video stream **10**.

When input video stream **10** is presented for encoding, each frame **16** within input video stream **10** is processed in units of macroblocks. At intra/inter prediction stage **26**, each macroblock can be encoded using either intra-frame prediction (i.e., within a single frame) or inter-frame prediction (i.e. from frame to frame). In either case, a prediction macroblock can be formed. In the case of intra-prediction, a prediction macroblock can be formed from samples in the current frame that have been previously encoded and reconstructed. In the case of inter-prediction, a prediction macroblock can be formed from samples in one or more previously constructed reference frames as described in additional detail herein.

Next, still referring to FIG. **2**, the prediction macroblock can be subtracted from the current macroblock at stage **26** to produce a residual macroblock (residual). Transform stage **28** transforms the residual into transform coefficients in, for example, the frequency domain, and quantization stage **30** converts the transform coefficients into discrete quantum values, which are referred to as quantized transform coefficients or quantization levels. The quantized transform coefficients are then entropy encoded by entropy encoding stage **32**. The entropy-encoded coefficients, together with the information required to decode the macroblock, such as the type of prediction used, motion vectors, and quantizer value, are then output to compressed bitstream **24**.

The reconstruction path in FIG. **2** is present to ensure that both encoder **20** and a decoder **42** (described below) use the same reference frames to decode compressed bitstream **24**. The reconstruction path performs functions that are similar to functions that take place during the decoding process that are discussed in more detail below, including dequantizing the quantized transform coefficients at dequantization stage **34** and inverse transforming the dequantized transform coefficients at an inverse transform stage **36** in order to produce a derivative residual macroblock (derivative residual). At reconstruction stage **37**, the prediction macroblock that was predicted at intra/inter prediction stage **26** can be added to the derivative residual to create a reconstructed macroblock. A loop filter **38** can then be applied to the reconstructed macroblock to reduce distortion such as blocking artifacts.

Other variations of encoder **20** can be used to encode compressed bitstream **24**. For example, a non-transform based encoder can quantize the residual signal directly without transform stage **28**. In another embodiment, an encoder may have quantization stage **30** and dequantization stage **34** combined into a single stage. In yet another embodiment, a temporal filter may be included with the intra/inter prediction stage **24**.

The encoding process shown in FIG. **2** can include two iterations or "passes" of processing the video data. The first pass can be carried out by encoder **20** using an encoding process that is less computationally intensive, and that gathers and stores information about input video stream **10** for use in the second pass. In the second pass, encoder **20** uses this information to optimize final encoding of compressed bitstream **24**. For example, encoder **20** may use this information to select parameters for encoding, locating key-frames and selecting coding modes used to encode macroblocks **18**, and allocating the number of bits to each frame. The output of the second pass can be final compressed bitstream **24**.

FIG. **3** is a block diagram of a video decompression system or decoder **42** to decode compressed bitstream **24**. Decoder **42**, similar to the reconstruction path of the encoder **20** discussed previously, includes the following stages to perform various functions to produce an output video stream **44** from compressed bitstream **24**: an entropy decoding stage **46**, a dequantization stage **48**, an inverse transform stage **50**, an intra/inter prediction stage **52**, a reconstruction stage **54**, a loop filter stage **56** and a deblocking filtering stage **58**. Other structural variations of decoder **42** can be used to decode compressed bitstream **24**.

When compressed bitstream **24** is presented for decoding, the data elements within compressed bitstream **24** can be decoded by entropy decoding stage **46** (using, for example, Context Adaptive Binary Arithmetic Decoding) to produce a set of quantized transform coefficients. Dequantization stage **48** dequantizes the quantized transform coefficients, and inverse transform stage **50** inverse transforms the dequantized transform coefficients to produce a derivative residual that can be identical to that created by the reconstruction stage in the encoder **20**. Using header information decoded from the compressed bitstream **24**, decoder **42** can use intra/inter prediction stage **52** to create the same prediction macroblock as was created in encoder **20**. At the reconstruction stage **54**, the prediction macroblock can be added to the derivative residual to create a reconstructed macroblock. The loop filter **56** can be applied to the reconstructed macroblock to reduce blocking artifacts. Deblocking filter **58** can be applied to the reconstructed macroblock to reduce blocking distortion, and the result is output as output video stream **44**.

Other variations of decoder **42** can be used to decode compressed bitstream **24**. For example, a decoder may produce output video stream **44** without deblocking filtering stage **58**.

Referring again to encoder **20**, video encoding methods compress video signals by using lossless or lossy compression algorithms to compress each frame or blocks of each frame of a series of frames. As can be implied from the description above, intra-frame coding refers to encoding a frame using data from that frame, while inter-frame coding refers to predictive encoding schemes such as schemes that comprise encoding a frame based on other so-called "reference" frames. For example, video signals often exhibit temporal redundancy in which frames near each other in the temporal sequence of frames have at least portions that match or at least partially match each other. Encoders can take advantage of this temporal redundancy to reduce the size of encoded data by encoding a frame in terms of the difference between the current frame and one or more reference frames.

As described briefly above, many video coding algorithms first partition each picture into macroblocks. Then, each macroblock can be coded using some form of predictive coding method. Some video coding standards use different types of predicted macroblocks in their coding. In one scenario, a macroblock may be one of three types: 1) Intra (I) macroblock that uses no information from other pictures in its coding; 2) Unidirectionally Predicted (P) macroblock that uses information from one preceding picture; and 3) Bidirectionally Predicted (B) macroblock that uses information from at least one past picture and at least one future picture.

To facilitate higher quality compressed video, it is helpful to have a matching reference frame in order to have the smallest difference to encode, which generally results in a more compact encoding. Reference frames are based on past frames, future frames, or an intra-frame so that the encoder can find a matching block to use in the predictive process as shown in, for example, U.S. Application Publication No.

2005/0286629. Reference frames can also be based on synthesized or constructed frames that are not shown to the end user after decoding, as shown in, for example, in U.S. Application Publication No. 2010/0061461 A1. Such constructed reference frames are referred to herein as "alternate reference frames." The alternate reference frames are constructed from macroblocks, which are referred to herein as "alternate reference blocks."

Another method of creating and using an alternate reference frame is described herein. FIG. **4** is a flow chart of a method of encoding with a new alternate reference frame synthesized using segmentation and motion compensation as implemented in the encoder of FIG. **2**. First, a reconstructed frame is selected and segmented (**60**). The reconstructed frame is obtained from the reconstruction path, and typically would be output from the loop filter **38**. For example, the reconstructed frame may be a golden frame, an original alternate reference frame, or a last frame to be encoded. The reconstructed frame may be segmented into two or more segments of at least one pixel using a variety of segmentation parameters. For example, the reconstructed frame could be segmented using color segmentation or motion segmentation.

Color segmentation divides a frame into segments based upon the colors presented in the captured image. More specifically, when a camera captures images, the original color, typically RGB, for each pixel is converted and stored as a signal including separate luminance (or luma) and chrominance (or chroma) values. That is, each pixel is represented by a luma value Y and by two values collectively forming the chroma value, a chroma value U and a chroma value V. Luma values Y of the image represent the achromatic portion of an image (that is, the image without color), while the chroma values U and V are sometimes called color difference components and generally represent the color of the image. Most commonly, each luma value Y is a weighted sum of gamma-compressed red, green and blue components (R'G'B') represented by Y', and chroma values U and V are respectively equal to B'-Y' and R'-Y' represented by Cb and Cr. Here, the actual color format is not critical or limited and can be any color format or colorspace.

Encoder **20** and decoder **42** code macroblocks **18** of frame **16** using image formats that rely on chroma, chrominance or chromatic sampling or subsampling. That is, because human vision is more sensitive to black and white differences than to chromatic differences, a lower sampling rate (fewer bits) can be used to represent the chroma values of pixels of each frame **16** than to represent the luma values of those pixels. By example, encoder **20** and decoder **42** can code macroblocks **18** using 4:2:0 YUV chroma subsampling. This scheme halves the amount of data as compared to an image with no chroma subsampling as only one chroma value for each of chroma values U and V is sampled for every four luma values Y. This essentially means that while there are two chroma values for each group of four image pixels, there are four luma values.

As described above, when input video stream **10** is presented for encoding, each frame **16** within input video stream **10** is processed into units of macroblocks. At intra/inter prediction stage **26** of encoder **20**, each macroblock can be encoded using either an intra prediction or inter prediction mode. The predictions for luma values Y and for chroma values U and V of pixels of the macroblock can be calculated independently of each other. Further, and in regard to the predictions for chroma values U and V, a prediction mode can treat these values identically (i.e., use the same relative addressing and arithmetic). In certain embodiments, predictions for chroma values U and V may be different. In the examples herein, pixels are considered with regard to their combined color value YUV.

Returning now to FIG. **4**, a frame can be segmented (**60**) by segmenting individual macroblocks or by segmenting the frame in its entirety. As one example, segmenting can be performed by quad-tree decomposition (or deconstruction). One implementation of quad-tree decomposition initially subdivides the image into four equal-size blocks and then selectively subdivides the smaller blocks in a like manner if the smaller blocks have more than one different color value YUV for pixels in that block. That is, each block is subdivided into groups of four until each set of blocks represents pixels having a same color value YUV.

Note that while each set of blocks is said to represent pixels having the same color value YUV, in actuality the pixels in a set have values Y, U and V that are not necessarily the same. Instead, the blocks are sub-divided by defining an acceptable variance for each of the values Y, U and V for the pixels that form each set of blocks. In this manner, each set of blocks can be represented by three representative values for luma and chroma values. The representative values can be average values using the luma and chroma values of the individual pixels comprising a set. Alternatively, the representative values could be some other combination of the respective luma and chroma values of the pixels comprising that set. As one example, each of the representative values for luma and chroma could be average values of only certain of the pixel values, such as those that fall within a defined range about a median value.

In the example above, partitioning continues until the number of values YUV in a set is equal to one (that is, all the pixel values Y, U, V are within a maximum variance). The frame and/or each macroblock could instead be partitioned into sets of pixels based on another desirable threshold. For example, partitioning could occur until a fixed number of sets is defined.

Segmenting a frame (**60**) is not limited to quad-tree decomposition and can be implemented by binary-tree or octree decomposition in a similar manner. Also, these methods of segmenting a frame can be combined such that part of the segmentation is performed by one decomposition method while another part of the segmentation is performed by another decomposition method.

Another method of segmenting a frame (**60**) involves k-means clustering techniques, or similar, to produce either the smallest set of entries that ensures the reconstruction error is below a defined threshold, or a fixed number of entries. As known to those skilled in the art, k-means clustering is a method that can be used to partition n values into k clusters where each value belongs in the cluster with the nearest mean. In this case, for example, the number k can be predetermined for either a macroblock **18** or frame **16** such that a fixed number of clusters results.

An alternative implementation could first use a k-means segmentation to split the entire frame (irrespective of block boundaries) into N regions and then use binary-tree or quad-tree decomposition to encode region membership. Decomposition is stopped when all pixels in a sub-region have the same region membership, which is then encoded as a leaf node.

While the descriptions above implement segmentation using color, in another embodiment the frame could be segmented (**60**) by motion segmentation. Motion segmentation allows for division of a frame by identifying as segments various components that are independently moving in an image. For example, the image deconstruction or k-means segmentation described above could be implemented using the magnitude and direction of a motion vector as the variables for each pixel to be considered. Motion segmentation would require at least two adjacent reconstructed frames to establish the movement needed for segmentation. Other types of segmentation are also possible and may be used, such as expectation-maximization clustering techniques.

Segmentation may result in any number of different segments, each segment having any number of pixels. The methods disclosed herein may be used with any shape or size segment. The number of segments is based on accuracy versus the amount of data to be encoded (i.e., the bit cost). More segments require more bits for encoding, but the fewer the number of segments, generally the less accurate the reconstruction of the segmented images. Known techniques for comparing the bit cost of various encoding options can be incorporated with the techniques described herein to determine a desired number of segments.

Referring back to FIG. **4**, once the segments have been determined (**60**), they are labeled with a segment identifier for processing (**62**). The segment identifier can be, for instance, a sequentially generated number created in the order of segment creation. Once the segments are labeled (**62**), a segment is selected for motion estimation processing (**64**). In this example where the motion parameter is a motion vector, a motion vector search is performed on the selected segment (**66**). A motion vector can be found by any motion estimation method such as full search or diamond search. One useful method is described in, for example, Hamosfakidis et al., "A Novel Hexagonal Search Algorithm for Fast Block Matching Motion Estimation," EURASIP Journal on Applied Signal Processing 2002:6, 595-600. Other methods are available and will be apparent to those skilled in the art.

Although this example describes motion estimation processing as searching for a motion vector (**66**), and the following steps describe using the motion vector as a motion parameter for the creation of the new alternate reference frame, the process described herein is not limited to using motion vectors to describe the movement of each segment. That is, segments may undergo movement other than no movement (zero motion vector) or simple translation (a motion vector having a non-zero magnitude and direction). Use of other motion parameters such as those associated with a zoom, a rotation or a shear is possible. Obtaining these motion parameters can be handled using an object based affine transform such as known to those skilled in the art. Examples of motion of a segment are described with respect to FIG. **7** hereinafter.

Once the motion vector for the selected segment is determined (**66**), the encoder **20** determines if the currently selected segment is the last available segment (**68**). If not, the next available segment is selected (**64**) and its motion vector is determined (**66**). Once a motion vector has been determined for each segment (**68**), a new alternate reference frame is created (**70**) using the segments and motion vectors. An exemplary process for creating the alternate reference frame is described in more detail later with respect to FIG. **6**.

Once the alternate reference frame is created, it is then available in the intra/inter prediction stage **26** for encoding frames (**72**). The identification of segments and their motion vectors are transmitted in compressed bitstream **24** (**74**) for use by the decoder **42** to recreate the alternate reference frame for decoding those blocks/frames encoded by encoder **20** with reference to the alternate reference frame. In one embodiment, it is desirable to transmit the segment and its motion parameter, such as the motion vector, only if that segment has greater than a minimum number of pixels, such as 20. Such segments may also optionally be omitted when creating the alternate reference frame.

As mentioned, each motion parameter (e.g., a motion vector) transmitted is associated with a segment. For example, the association can be made by transmitting the segment identifier along with each motion vector. Additionally, an identifier of the segmentation parameters and method used to segment the frame may be transmitted to the decoder **42** so that the decoder **42** can recreate the same segments. Alternately, the segmentation parameters and method may be pre-negotiated between the encoder **20** and decoder **42** so that they need not be transmitted each time in step **74**.

FIG. **5** is a flow chart of a method of decoding with a new alternate reference frame synthesized using segmentation and motion compensation as implemented in the decoder of FIG. **3**. First, a frame to be decoded is identified (**80**). In this example, the frame to be decoded was encoded by the encoder **20** using the alternate reference frame described with reference to FIG. **4**. Once the frame is identified, the segmentation parameters used to segment the frame by the encoder **20** are determined (**82**). As described above, the segmentation parameters may be transmitted in the compressed bitstream **24** along with the frame to be decoded or may be pre-negotiated between the encoder **20** and decoder **42**.

Once the segmentation parameters and method are determined, decoder **42** will then segment the frame to be decoded (**84**). The alternate reference frame will be created using motion vectors and segment labels encoded into the compressed bitstream **24** (**86**). An exemplary process for creating the alternate reference frame is described in more detail later with respect to FIG. **6**. Once the alternate reference frame has been created, the frame to be decoded will be decoded using the new alternate reference frame (**88**).

Now, with respect to FIG. **6**, a method of creating a new alternate reference frame using segments and motion vectors is described. The method uses segments and motion vectors as provided by either the encoder **20** or decoder **42** as described with respect to FIGS. **4** and **5** above. First, a frame is initialized with initial pixel values (**100**). The initial pixel values may be any desirable default value, such as zero. Each pixel is initially marked as unfilled (**102**).

A first segment is selected (**104**) thereafter, and the motion vector related to the segment is looked up (**106**). The motion vector may be associated with the segment by way of a segment identifier as described previously.

A pixel in the segment is then selected (**108**). The new location of the pixel is calculated using the previously selected motion vector. Alternatively, the pixel may have more than one new location, depending on the type of motion parameter associated with the segment. Once the at least one new location is determined, the pixel is copied to that at least one new location (**110**). In some implementations, calculating the new location of the pixel may include comparing the new location to a range of locations of the alternate reference frame to determine whether the new position is within the range of positions of the alternate reference frame, and copying a value associated with the pixel in the new position in the alternate reference frame if the new position is within the range of positions of the alternate reference frame.

Typically, the pixel will be copied to the new location even if that pixel location already has been filled with a pixel from another segment. But alternatively, the new pixel may be averaged or by some other means combined with the pixel that was previously copied. The new location is then marked as a filled location (**112**). If there are additional pixels in the current segment to be processed (**114**), the next pixel is selected (**108**), the new pixel is copied to its new location (**110**), and the new located in marked as filled (**112**). This process repeats until all pixels in the current segment are moved by the segment's motion vector (**114**).

If additional segments need to be processed (**116**), a new segment is selected (**104**) so as to move its pixels in accordance with the motion vector for that new segment. Otherwise, a first pixel from the alternate reference frame is selected (**118**). A query is then made as to determine whether the pixel has been filled (**120**). If the pixel is not marked as filled, the pixel is filled (**122**). The pixel may be filled by, for example, determining the value of a nearby filled pixel and copying that pixel value to the currently selected unfilled pixel. Alternatively, the pixel may be filled by calculating an average value of nearby filled pixels. The pixel may be filled by copying a pixel from a reconstructed frame. Other methods of filling unfilled pixels are available and may be used.

Once the unfilled pixel has been filled (**122**) or if the current pixel was already filled (**120**), the method determines whether there are additional pixels to process (**124**). If so, control returns to select the next available pixel (**118**). Otherwise, the method ends as the new alternate reference frame is completed.

FIG. **7** is a schematic diagram illustrating exemplary frames of a video bitstream as used and created by the methods of FIGS. **4**-**6**. FIG. **7** shows an exemplary application of color segmentation. The figure includes a reconstructed frame X **150**. The reconstructed frame X **150** can include macroblocks, such as macroblock **152**. Reconstructed frame X contains a circular object **154**. In this example, circular object **154** contains color values distinct from the remainder of the reconstructed frame X **150**.

Circular object **154** occupies space within a macroblock cluster **156**. Each macroblock in macroblock cluster **156** may include one or more pixels comprising circular object **154**. For example, macroblocks **156***a*-*d* contain a varying percentage of pixels that are a part of circular object **154**. For example, while macroblock **156***d* is entirely inclusive of circular object **154** pixels, only a small portion of macroblock **156***c* includes circular object **154** pixels.

The application of reconstructed frame X **150** to the new alternate reference frame encoding method described in FIG. **4** will now be described. As applied to the method, reconstructed frame X **150** is analogous to the reconstructed frame of step **60**. The circular object **154** portrays an exemplary segment that could, for example, be created in the segmentation process of steps **60** and **62**. The exemplary segment, in this case, is defined by the color of circular object **154**.

The segment is defined at a granularity of size less than a macroblock. For example, the entire macroblock **156***c* is not included in the segment defined by circular object **154**, since circular object **154** only has a small number of pixels within macroblock **156***c*.

The segment of circular object **154** can be used to predict other frames, such as original frame Y **160**. Original frame Y **160** also includes macroblocks such as macroblock **162**. Original frame Y **160** includes a second circular object **164**. In this example, circular object **164** is the same size, shape, and color as circular object **154**, but is in a different location within the frame. The relative location is illustrated by the dotted circle indicating the position of circular object **154** with respect to original frame Y **160** (**154'**).

To utilize reconstructed frame X **150** as a basis for a new alternate reference frame **170** for original frame Y **160**, a motion vector **166** must be determined for the exemplary segment. The motion vector **166** is determined as discussed in the motion vector search step **66**. The new alternate reference frame **170** is created using the reconstructed frame X **150**, the exemplary segment corresponding to the circular object **154** and the motion vector **166**. The process of creating the new reference frame is as defined in step **70** and in the method of FIG. **6**.

The exemplary segment is moved pixel by pixel into the new alternate reference frame **170**, creating a second circular segment predictor **176**. The new alternate reference frame **170** is composed of macroblocks such as macroblock **172**. Even though the second circular object predictor **176** is within a macroblock cluster **174**, only the pixels needed to create the second circular object predictor **176** are moved. Every pixel within macroblock cluster **174** is not necessarily moved to create the new reference frame.

The segment of circular object **154** can also be used to predict another frame, such as original frame Z **180**. Original frame Z **180** also includes macroblocks such as macroblock **182**. Original frame Z **180** includes a third circular object **184** that is the same shape and color as circular object **156**, but is in a different location within the frame and is a larger size. Essentially, this reflects the existence of movement of third circular object **184** indicating both a zoom and a simple translation. The relative location is illustrated by the dotted circle indicating the position of circular object **154** with respect to original frame Z **180** (**154"**).

The third circular object **184** illustrates the application of more than one motion parameter to the segment of circular object **154** to create an alternate reference frame **200**. Alternate reference frame **200** includes blocks such as macroblock **202**. Motion vector **186** illustrates the transposition of the position of the circular object **156** to the position of circular object **184**. The new position of circular object **154** after applying motion vector **186** is shown by the dotted circle location **188**. The arrows **190** depict a zoom-type operation on circular object **154** at location **188** that would be represented by other motion parameters. These multiple motion parameters would be determined, for example, in the motion vector search (**66**) of FIG. **4**.

The exemplary frames shown in FIG. **7** are included purely for illustrative purposes to demonstrate one application of the methods described above. Numerous other applications, including those with much more complex frames and segments are possible. In addition, variations of the methods disclosed above may be used. These variations may have more or less steps or may perform steps in different orders. For example, the segment labeling (**62**) of FIG. **4** may not be performed, or elements of segment labeling (**62**) may be performed within another step, such as segmenting the reconstruction frame (**60**). Another exemplary modification may be to perform the motion vector search (**66**) for each segment in parallel instead of sequentially (**64**, **66** and **68**) as shown in FIG. **4**.

The operation of encoding can be performed in many different ways and can produce a variety of encoded data formats. The above-described embodiments of encoding or decoding may illustrate some exemplary encoding techniques. However, in general, encoding and decoding are understood to include any transformation or any other change of data whatsoever.

Encoder **20** and/or decoder **42** (and the algorithms, methods, instructions etc. stored thereon and/or executed thereby) can be implemented in whole or in part by one or more processors which can include computers, servers, or any other computing device or system capable of manipulating or processing information now-existing or hereafter developed including optical processors, quantum processors and/or molecular processors. Suitable processors also include, for example, general purpose processors, special purpose processors, IP cores, ASICS, programmable logic arrays, programmable logic controllers, microcode, firmware, microcontrollers, microprocessors, digital signal processors, memory, or any combination of the foregoing. In the claims, the term "processor" should be understood as including any the foregoing, either singly or in combination. The terms "signal" and "data" are used interchangeably.

Encoder **20** and/or decoder **42** also include a memory, which can be connected to the processor through, for example, a memory bus. The memory may be read only memory or random access memory (RAM) although any other type of storage device can be used. Generally, the processor receives program instructions and data from the memory, which can be used by the processor for performing the instructions. The memory can be in the same unit as the processor or located in a separate unit that is coupled to the processor.

For example, encoder **20** can be implemented using a general purpose processor with a computer program that, when executed, carries out any of the respective methods, algorithms and/or instructions described herein. FIG. **8** illustrates one suitable implementation in which encoder **20** is implemented in a general purpose computer including a central processing unit (CPU) **212** and random access memory (RAM) **214**. Decoder **42** is implemented using a general purpose computer including a central processing unit (CPU) **216** and random access memory (RAM) **218**. In addition or alternatively, for example, a special purpose processor can be utilized which can contain specialized hardware for carrying out any of the methods, algorithms and/or instructions described herein. Portions of encoder **20** or decoder **42** do not necessarily have to be implemented in the same manner. Thus, for example, intra/inter prediction stage **26** can be implemented in software whereas transform stage **28** can be implemented in hardware. Portions of encoder **20** or portions of decoder **42** may also be distributed across multiple processors on the same machine or different machines or across a network such as a local area network, wide area network or the Internet.

Encoder **20** and decoder **42** can, for example, be implemented in a wide variety of configurations, including for example on servers in a video conference system. Alternatively, encoder **20** can be implemented on a server and decoder **42** can be implemented on a device separate from the server, such as a hand-held communications device such as a cell phone. In this instance, encoder **20** can compress content and transmit the compressed content to the communications device, using the Internet for example, as shown in FIG. **8**. In turn, the communications device can decode the content for playback. Alternatively, the communications device can decode content stored locally on the device (i.e. no transmission is necessary). Other suitable encoders and/or decoders are available. For example, decoder **42** can be on a personal computer rather than a portable communications device.

The operations of encoder **20** or decoder **42** (and the algorithms, methods, instructions etc. stored thereon and/or executed thereby) can be realized in hardware, software or any combination thereof. All or a portion of embodiments of the present invention can take the form of a computer program product accessible from, for example, a computer-usable or computer-readable medium. A computer-usable or computer-readable medium can be any device that can, for example tangibly contain, store, communicate, and/or transport the program for use by or in connection with any processor. The medium can be, for example, an electronic, magnetic, optical, electromagnetic, or a semiconductor device. Other suitable mediums are also available.

The above-described embodiments have been described in order to allow easy understanding of the present invention and do not limit the present invention. On the contrary, the invention is intended to cover various modifications and equivalent arrangements included within the scope of the appended claims, which scope is to be accorded the broadest interpretation so as to encompass all such modifications and equivalent structure as is permitted under the law.

What is claimed is:

1. A method for encoding a current frame of a video signal having a plurality of frames, each frame having a plurality of pixels, the method comprising:

segmenting a previously reconstructed frame into a plurality of image segments using a segmentation parameter, at least one image segment from the plurality of image segments having a segment identifier;

determining, using a processor, a motion parameter for each respective image segment from the plurality of image segments;

creating an alternate reference frame from the previously reconstructed frame using the motion parameter for each respective image segment from the plurality of image segments; and

encoding the current frame using the alternate reference frame for motion prediction.

2. The method of claim **1** wherein the previously reconstructed frame is one of a golden frame, an original alternate reference frame, or a last frame to be encoded.

3. The method of claim **1**, further comprising:

identifying an association between the current frame and the previously reconstructed frame;

identifying an association between the current frame and the motion parameter for each respective image segment from the plurality of image segments; and

identifying an association between the current frame and the segmentation parameter.

4. The method of claim **3**, further comprising: including at least one of the identified associations in the encoded output.

5. The method of claim **1** wherein segmenting the previously reconstructed frame comprises using at least one of color segmentation or motion segmentation, and the segmentation parameter comprises at least one of a color or a motion vector for each pixel of the previously reconstructed frame.

6. The method of claim **1** wherein segmenting the previously reconstructed frame comprises performing at least one of k-means clustering, binary tree deconstruction, quad-tree deconstruction, or oct-tree deconstruction.

7. The method of claim **1** wherein determining the motion parameter for each respective image segment from the plurality of image segments comprises:

performing a motion vector search on pixels making up each respective image segment from the plurality of image segments; and

selecting a motion vector based on the motion vector search for each respective image segment from the plurality of image segments as the motion parameter.

8. The method of claim **1** wherein creating the alternate reference frame comprises:

calculating a new position for each pixel of each respective image segment from the plurality of image segments using the motion parameter of each respective image segment from the plurality of image segments;

comparing the new position to a range of positions of the alternate reference frame; and on a condition that the new position is within the range of positions of the alternate reference frame, copying a value associated with the pixel in the new position in the alternate reference frame.

9. The method of claim **1** wherein creating the alternate reference frame comprises:

for each image segment in the plurality of image segments:

calculating a new position for each pixel of the image segment using the motion parameter of the image segment;

comparing the new position to a range of positions of the alternate reference frame; and

on a condition that the new position is within the range of positions of the alternate reference frame, copying a value associated with the pixel in the new position in the alternate reference frame.

10. The method of claim **9** wherein creating the alternate reference frame comprises:

selecting an unfilled pixel of the alternate reference frame that has no value copied to it after values for all pixels of the previously reconstructed frame having the new position within the range of positions of the alternate reference frame are copied into the new position in the alternate reference frame;

determining a desired value for the unfilled pixel; and

copying the desired value to the unfilled pixel.

11. The method of claim **10** wherein determining the desired value comprises selecting one of a value of a nearby filled pixel, an average of more than one nearby filled pixel, or a value of the pixel at the same location in the current frame to be encoded.

12. The method according to claim **9**, further comprising:

initializing values for each pixel in the alternate reference frame to zero and labeling each pixel in the new frame as unfilled before comparing the new position to the range of positions of the alternate reference frame; and

on a condition that the new position is within the range of positions of the alternate reference frame, changing a label for the pixel to filled.

13. The method of claim **1** wherein the motion parameter for each respective image segment from the plurality of image segments is at least one of a motion vector or a parameter reflecting at least one of a zoom, a rotation, or a shear of the image segment.

14. The method of claim **1** wherein creating the alternate reference frame from the previously reconstructed frame includes omitting an image segment and a respective motion parameter, wherein the image segment includes fewer than a predetermined number of pixels.

15. The method of claim **1**, wherein encoding the current frame includes using the alternate reference frame for motion prediction in response to determining whether to use the alternate reference frame or the previously reconstructed frame for motion prediction.

16. The method of claim **1**, wherein the alternate reference frame is not a reconstructed frame.

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